A RETHINK FOR COMPUTING EDUCATION FOR SUSTAINABILITY

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ABSTRACT

The premise of Computing Education for Sustainability (CEfS) is examined. CEfS is described as a leverage discipline, where the handprint is much larger than the footprint. The potential of this leverage is described and the development of the field explored. Unfortunately CEfS is found not to be making sufficient impact in terms of a contribution at scale to system change actions resulting in restorative socio-ecological transformation. The paper considers why this might be, and what could be done about it. Two inspirations are described - a case study of a learner with an ambitious change aspiration, and a values-driven business. These lead to the presentation of an alternative model which while not exhaustive, is intended to provoke debate about the nature of computing education for sustainability.

KEYWORDS

Education, sustainability, computing

1. INTRODUCTION

The fields of education, computing and sustainability coalesce in Computing Education for Sustainability (CEfS). This can be seen as the combination of two disciplines with very high leverage, for change in a third arena - where the handprint, the potential to do good, is massively greater than the negative impact, the footprint. This CEfS should have the potential to be a significant agent for change. In this paper, however, I argue that we have largely failed in this mission, and a radical rethink is needed. Sustainability is considered here in terms of system change actions resulting in restorative socio-ecological transformation.

2. CEfS POTENTIAL

2.1 Education

Education can be considered a leverage discipline. Our service – our potential to do good – is vastly greater than our negative impact. Education for Sustainability (EfS) is fundamental to the global Sustainable Development Goals and most, if not all tertiary organisations have begun to address the operational aspects of sustainability. Many tertiary organisations can point to some element of their curriculum that focuses on sustainability. But few have addressed EfS in a holistic, multidisciplinary and systematic manner.

Otago Polytechnic is one tertiary organisation that has at least attempted this holistic EfS. In 2007 it adopted as a core strategic objective the statement that "every graduate may think and act as sustainable practitioner". With some tweaking of the wording, it remains so in 2016 - as illustrated in the opening paragraph of Otago Polytechnic's Annual Report:

> *"Guiding our students through a formative time in their lifelong learning journeys is a special privilege. At Otago Polytechnic, they engage in an experiential learning process and emerge as capable, work-ready, future-focused and sustainable practitioners".*

The Otago Polytechnic sustainability journey is explored in The Green Graduate (Mann 2011) and The Simple Pledge (Mann and Ellwood 2009). Rather than specifying a pre-determined set of behaviours to describe sustainability within a discipline, instead we aim to take students on a journey of themselves identifying what it means for them to think and act as a sustainable practitioner. In 2013, 93% of graduates agreed with the statement that "my learning experience developed my understanding of social, environmental and economic sustainability". In the Graduate Employer Survey (2012 data), 94% of employers rated "Demonstrate an understanding of social, environmental and economic sustainability" as a criteria for employment as very high, high or moderate, and 87% agreed that Otago Polytechnic graduates demonstrated this attribute. In 2013, the international benchmark AUSSE survey asked respondents to rate the learning experience on a number of dimensions, including "the learning experience…contributes to living in a sustainable way". Otago Polytechnic respondents were considerably more agreeable than the benchmark (58% agree, national and international benchmark groups both 35% agree).

2.2 Computing

Computing also has the promise of being a leverage discipline. Despite a very large and troubling footprint, the potential handprint of computing is far greater.

Computing's footprint is indeed troubling. Even if we just consider climate change (and we shouldn't as sustainability is very much wider than that, but energy and carbon are useful proxies), computing's infrastructure contributes about 2% of anthropogenic greenhouse gas emissions (Preist and Mann 2013, Raghaven and Mann, 2016) - about that of the aviation industry.

This problem is huge and we need to do everything we can to reduce this burden on the planet. But our potential handprint is bigger, much bigger. If we just consider climate change (again noting the qualification on this narrowing), Skip Laitner estimates that our society runs on about 14% energy efficiency "we are wasting most of what we produce" (Laitner *et al.* 2014). While not the only solution – we need to consume less too – a big chunk of the gain Laitner describes can only come from ICT enabled systems improvements, perhaps as much as 30-40%.

2.3 CEfS

So, education has a high potential leverage, and computing has a high potential leverage. The potential for combining them as Computing Education for Sustainability (CEfS) is very appealing. In terms of making a difference - contributing to a socio-ecological transformation, this could make a big impact.

In practice, Otago Polytechnic's computing degree has seen a wide variety of sustainability related capstone projects performed for industry "client" partners.

- An app for managing wildlife interactions on beaches
- A device for mapping cycle-traffic "near miss" passing interactions
- A local food cooperative
- A home-based solar power management
- An electric vehicle control system
- A hybrid physical and digital social enterprise education game
- A support system for disadvantaged and vulnerable learners
- A game for teaching sustainability via a farming simulation.
- A game for teaching peace and conflict resolution
- A system for supporting distributed funding for charities
- A management system for reusing eWaste
- A food footprint calculator
- A source map for local food
- A citizen science based tool for rocky shore environments.

Sustainability is not a requirement for the capstone, but it is interesting to note that in their last major projects, and without a requirement, students are seeing this area as a useful vehicle for integrating skills learnt in the degree and that industry clients are seeing value in these projects.

In 2007, we began a series of papers on an agenda for computing education for sustainability. We first linked sustainability and computing, quoting United Nations Secretary-General Ban Ki-Moon who argued that that "information and communications technologies (ICT) are crucial in spurring development, dignity and peace". He argued that we should "turn the digital divide into digital opportunity" and that ICT should be promoted "in fighting poverty, illiteracy and disease, in protecting the environment and empowering women and girls". We stated that "as computing professionals we need to examine what role we see computing professionals playing in that future. As computing educators charged with creating those computing professionals we are doubly responsible, as we also have put in place the system to get us there" (Mann and Smith 2007a). In Mann and Smith (2007b) we took up this challenge and described the drivers for an emergent field of Computing Education for Sustainability. We explored options for including sustainability in computing qualifications. We looked for, but couldn't find whole degrees in Sustainable Computing, indeed whole courses were similarly elusive. Our preferred approach was one of "critical inquiry and integration throughout the curriculum in ways that are both incremental and transformative" (2007a).

The paper (Mann and Smith 2007b) concluded with a suggested agenda for developing CEfS. After further workshopping at a national conference, an agenda was agreed by the National Advisory Committee on Computing Qualifications (NACCQ). NACCQ (then its successor organisation CITRENZ) added sustainable practice to all computing qualifications. Most recently, in 2013-2015, all sub-degree computing qualifications were completely rewritten in government mandated review. All such New Zealand computing qualifications now include explicit requirements for sustainable practitioners in the graduate profile outcomes. On an international level, a series of workshops at ACM's ITiCSE conference (Mann *et al.* 2008, Mann *et al.* 2009, Goldweber *et al.* 2013) brought CEfS to the attention of international computing educators. The eventual outcome of this was the recognition of the sustainable practitioner in the ACM CS2013 Core Curriculum as a Core Tier 1: "Identify ways to be a sustainable practitioner".

3. WHY NOT A SUCCESS?

Unfortunately, if we return to sustainability in terms of system change actions resulting in restorative socio-ecological transformation, little progress has been made.

If we take the example of Human Computer Interaction (HCI), seminal papers such as Blevis' Sustainable Interaction Design (2007) prompted a flurry of research in sustainable HCI. However, as Brynjarsdottir *et al.* (2012) found, much of the resultant research is weak and focusses on a limited framing of sustainability and human behaviour, or, as Meyers and Nathan (2016) bleakly described, with an "impoverished" focus.

Computing does need to address its own footprint and it needs to educate people to do this. And it does need to maximise its handprint, and again we need to educate people to do this. But so far we have been very poor at the handprint, and even in the footprint have gotten largely stuck on energy efficiency, with limited effectiveness and quite possibly doing sustainability a disservice through misaligned values (Knowles *et al.* 2013, Knowles *et al.* 2014).

Beyond climate change, it is not hard to trace the footprint of impacts of computing on environmental degradation and social justice - as an example, to follow the pathways from our mobile devices to the inhumane conditions of the "artisan" cobalt miners of the Congo.

On the handprint side, computing for sustainability cannot be just about efficiency gains, and the problem is not just about carbon or energy. How can computing help reverse biodiversity loss? Or massive global inequities? Nor is it just about "the environment" – the systems in question are as much social as they are biophysical. As a society we have to learn to live in a complex world of interdependent systems with high uncertainties and multiple legitimate interests. These complex and evolving systems require a new way of thinking about risk, uncertainty, ambiguity and ignorance (Stagl 2007). These systems require that we can think simultaneously of the drivers and impacts of our actions across scales and barriers of space, time, culture, species and disciplinary boundaries. It means that we need to switch from a focus on outcomes to one of process. Ethics and sustainability can often be described as wicked problems - rarely as simple as choosing between an obvious good and an obvious bad. We need to be thinking about every decision, every action contributing to a system operating under ethical principles. Sustainability provides a framework for expanding ethical reasoning to a complex world.

While we can identify small pockets of CEfS that approaches the goals of the previous paragraph, as a whole the situation can perhaps be best described by Meyer and Nathan's "impoverished sustainability".

Stephen Stirling (2004) argues that education for sustainability must be transformative for the learner, and to achieve that, education itself must be transformed. The remainder of this paper asks the question, if we were to transform computing education for sustainability, what might it look like? I do not provide any definitive answers to this, but offer two inspirations for this reframing. The last section discusses implications.

4. INSPIRATION 1: RIMU BODDY

Rimu Boddy is making New Zealand's Quota Management System easier to use, improving compliance, and adding value to the fishing industry (Rimu's name and story are used here with permission). He graduated with a Bachelor of Information Technology from Otago Polytechnic in 2012. Rimu was not an A+ student but he came with a very strong passion - to make a difference in the fishing industry.

Imagine the reckless swearing alcoholic rough fisherman. That's me. And still is.

Rimu was dissatisfied with the way the Quota Management System worked in practice. It was not realistic to expect fishermen to complete a complex paper form every time they put the net out. Unsurprisingly, compliance was low, as low as 15%.

I had an idea - and went to Otago Polytechnic to make it real.

I left fishing to go to Otago Polytechnic with a loose idea to use IT to do something better for fishing in terms of information flow - or something, I knew there were gaps.

Rimu had an idea, that technology could be harnessed to improve the information flow, but he realised he needed to gain the skills to develop his idea. His focus during the degree was almost entirely on his idea.

Throughout each class - I asked questions directly relating to the project. This got annoying, but the tutors always answered - even when we go a bit off topic.

Business analysis was basically what the preliminary project was for me.

This was when things started to take shape.

The going was tough, both financially and academically

I had a son, had very little money saved.

I worked at nights at the newspaper - and struggled to understand Java. The bits I'd missed in the 1st year were crippling. But over time and with lots of study - the details started to sink in

Rimu's capstone project was always going to be on his fisheries system - by now referred to as "fish bucket".

I spoke to lecturers early on regarding the possibility of creating something as a third year project.

The reaction was completely supportive.

3rd year project, came with much excitement.

The same core concepts I learned in the 3rd year I still apply today. Loads of public speaking - in front of the class and more was another key element.

The other half of what was needed - making something that users can actually use was all the "other work" - what I still see as the bulk of any project; that process was laid bare in the 3rd year project, the absolute messiness of it all.

During the final year of his IT degree, Rimu entered in the student business entrepreneurship competition and emerged a category winner, and eventually winning the National Business Review student business competition.

By the end of the 3rd year - scraping through a few classes I had a business model and a software model. Some lasting friendships, and - a barely working set of prototypes. And all the connections I would need to move the project into a business.

The following years, Rimu continued to work on his project with a business incubator, supplementing his income with work for other organisations, and returning to fishing.

Toward the end of that year I was hired as a tester for HPSport - through connections at the Polytech.

I managed to upskill there while - working with Dunedin based Upstart to try to get the project into production with Talley's.

Underfunded and under skilled I couldn't pull it off despite Conrad Anderson's and my best efforts, we couldn't get traction.

During that time, Rimu was the client for a further BIT capstone project

Otago Polytech provided us with a student to do part of the project as a 3rd year project that went seriously well.

And the roller-coaster development continued:

The initial trials went well but I ran out of money and went back to Fishing for 4 months.

The electronic reporting solution CEDRIC was seen as too big and powerful to replace, and the integration with it was both legally and technically tricky. The timing wasn't yet right. The Ministry were beginning to scope out a similar project - based around compliance and surveillance.

I was introduced to 2 skippers and we gained dispensation for them to use the system for real. Initial trials were a success and I was invited to Auckland to meet with AFL.

We decided to team up - and bring the two projects into one business

The business is making a difference

Now we have trials with 3 fishing companies - we are in constant contact with the Ministry and are consulting with them on their compliance project.

We are helping to shape the way fishing is assisted by technology and bringing in added value throughout the whole process.

And new opportunities and challenges emerge

We have 5 employees - and couple part time. I spend my days developing mostly and other times Business direction and strategy. We are currently attempting to enter the US.

If I was to return to study it would be communications - to be honest I really need a refresher right now!

Rimu is now acting as client for the capstone projects for six Information Technology students.

Everything is difficult - at every level it gets harder. Coping strategies fail, and have to make new ones. But determination and having the support of others makes it all possible.

At every step the Polytech has been there for support connections and ideas long after the degree was all done and finished.

Rimu's learning pathway is unique, but his approach is not. Many students come to learning with a passion or a specific goal in mind, only to have that aspiration dulled by squeezing it into a fixed curriculum.

5. INSPIRATION 2: SUSTAINABILITY MATURITY

The child's bike manufacturing company, Wishbone Design Studio is owned and managed by Rich Latham and Jan McIvor (2016). The business is values-led, entirely based on a framework of sustainability and quality. Wishbone's dream was for a product that would last from ages one to five, and then be passed on to the next young rider. They wanted a principle of a 100% repairable product "that would never end up in the landfill" and they actively promote a second-hand market. A recent product innovation is the use of recycled carpet for the bike frame. The role of values infuses the business and the relationship with customers "because we declared our values early on – sustainability and quality – we were attracting customers of that same ilk, the pressure on us was not to drop standards, but to raise them".

On Willard's sustainability maturity model (2004), Wishbone is operating at the highest level "Sustainability-based thinking, perspectives, and behaviours are integrated into everyday operating procedures and the culture of the organization". Although anecdotal, I'm yet to find a computing organisation (research or commercial) above three on this scale: "Stage three is about incremental, continuous improvements in eco-efficiency".

It would be useful for CEfS to consider positioning itself on Willard's scale. What would computing education for sustainability look like if we did it from the same mindset as Wishbone does business? Can we imagine CEfS imaginering around strong values positions, making then breaking conventions?

6. IMPLICATION

What might these inspirations mean for CEfS? I believe that the original framing of CEfS didn't go nearly far enough.

If we look at the description of the agenda described in Mann and Smith (2007b) the preamble states:

"We hope that it is empowering and engaging. It is deliberately both top down and bottom up. It is deliberately both incremental and transformative. It is deliberately aimed at the champions and the "ordinary lecturer". It deliberately challenges (without pushing anything "down my throat") and provides resources to encourage".

In retrospect, perhaps we should have challenged more. Just putting a bit of recycling and procurement into the hardware course is not enough. While we may have gotten to a point where sustainability is in many computing qualifications, perhaps this "sustainability as usual" is doing a disservice.

Maybe rather than carefully aligning sustainability with the discipline, we need to be pointing out how much change is required. Huish's (2013) teaching of Development Activism, or "Dissent 101" might be a useful model here.

6.1 Alternative

CEfS has largely been carried out within existing education pedagogy. Otago Polytechnic has adopted a heutagogical-based teaching and learning strategy that has radical impact for education. The strategy can be considered with a device recognisable to those familiar with software engineering's Agile Manifesto:

At Otago Polytechnic we have to come to value:
Processes of learning over focus on content
Lecturers as co-learners over lecturers as experts
Learner-managed learning over lecturer delivered learning
Learner-negotiated projects over lecturer defined projects
Assessment as a learning process over assessment as a summative process
Flexible learning opportunities over timetabled teaching times
That is, while we value the items on the right, we value the items on the left more.

Exemplifying this approach is the work-based learning approach of CapableNZ - the Otago Polytechnic school of professional practice. This school works with learners to recognise and extend learning in a professional work-based context at both undergraduate and post-graduate levels. At undergraduate levels CapableNZ works with learners to align their professional framework of practice - their professional identity - with graduate profiles, including the computing degree. These learners would be expected to learn new areas, mostly to wrap their practice in theoretical context, but there are no formal classes. Instead the focus is on reflection.

On the basis that sustainability problems are not amenable to single-point interventions (because they are both wicked and numerous), we need a step-change in how we approach computing for sustainability. Rather than trying for separate interventions for every aspect, or for passive awareness, focus needs to be placed upon engaging people to affect worldviews. This deeper engagement might be through community conversations, through reflection and action research. Some computing researchers are beginning to recognise this as the next step (Silberman *et al.* 2014). Batya Friedman's (2016) multi-lifespan information systems have really looked at how we might start to address intergenerational equity. Some are working on community engagement, not as a means for behaviour change, but for the sake of an empowered community: Steve Benford's trajectories and uncomfortable interactions (Benford 2013), University of Lancaster's work on Tiree (Ferrario *et al.* 2014), Rob Comber's empowering communities (Comber 2016) and David Green's participatory documentary making (Green 2016). These research directions are supporting communities to create sustainable futures beyond a behaviour-change-intervention-via-new-product paradigm.

In order to contribute to this engagement focussed computing for sustainability, education also has to change. Bennett (2008) describes "anupholesteraphobia: the fear of not being able to cover the material" where the solution is not to try and cram more material into an already crowded curriculum, but rather to see sustainability as the context, a basis for deeper learning, or even a reason for learning.

Instead of formally teaching computing (or any other discipline for that matter), Education for Sustainability could focus on professional development and work practice - where that work is explicitly sustainability. Could we market a "Bachelor of Making a Difference" where learners are supported to undertake major projects - such as Rimu's fisheries logistics development? Learning of technical content would be on-demand as needed for the project. In Rimu's case, that on-demand learning would have included a lot of computer science, but also business management, policy development and marketing. It wouldn't be a Computer Science degree, but it would have been better in supporting his aspiration and career – and making a real difference for a sustainable future.

7. CONCLUSION

This work has been prompted by the author's increasing unease with the ability of CEfS to deliver a professional workforce committed and capable of the leverage that computing has promised in sustainability. This paper has argued that we need to step outside our comfort zone and engage in an activist approach to computing education. Previous attempts to demonstrate how sustainability fits into a computing education paradigm has not resulted in the required contribution at scale to system change actions resulting in restorative socio-ecological transformation. An alternative model is presented, which while not exhaustive, is intended to provoke debate about the nature of computing education for sustainability.

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